5

453-201

08/734346

IMPROVED TUNING MEANS FOR FULCRUM TREMOLO

BACKGROUND OF THE INVENTION

In a stringed musical instrument, such as a guitar, the strings extend unsupported between a first critical point usually formed by the nut where the neck joins the head and a second critical point usually formed by the bridge positioned on the body. The strings are anchored at one end on a portion of the instrument known as the tailpiece, strung over the bridge and the nut on the head of the instrument and in conventional instruments anchored on the other end to the tuning pegs where an untensioned string is tensioned and adjusted to a tuned condition. The second critical point is formed by a part of the bridge or by a part of a combined bridge and tailpiece structure. Traditionally, the size of the bridge elements are quite small so as to create a clearly defined single point of contact between the string and the bridge element. It is between these two points that the string length is determined. This is sometimes referred to as the scale length. Adjusting the relative distance between the first and second critical points is called harmonic tuning. Some bridges structures have individually adjustable bridge elements for each string. Often, the typical construction of the strings, particularly for guitar and bass, has a plain end and a "ball end" where a washer-like addition is wrapped by the string itself as a means to help secure the string to the instrument at the tailpiece. The wrapping usually extends for at least a 1/2" towards the plain end and as such the tailpiece structure must insure that the wrapping does not extend over the second critical point when arranged on the instrument. Fine tuning has been a long standing problem for stringed musical instruments.

2

In the Proelsdorfer U.S. Pat. No. 2,304,597, string tensioning devices placed on the tailpiece for fine tuning the pitch of the strings of violins, guitars and the like, were disclosed, however such pitch adjustment is quite limited in range and designed to offer the tuning of the strings a minor adjustment of pitch after the general tuning is achieved with the tuning pegs on the head of the instrument which in part provides the means for raising and adjusting the tension of the strings to pitch from an untensioned condition.

It is known to those skilled in stringed musical instrument design and construction that various tremolos have been proposed and utilized for varying the tension of all the strings simultaneously for the purpose of creating a tremolo sound. Further, it is known to those skilled in the art that there are a great many commonly used names for such devices, such as tremolo, tremolo device, tremolo tailpiece, tremolo bridge, fulcrum tremolo, fulcrum tremolo bridge, fulcrum tremolo tailpiece, fulcrum tremolo bridge-tailpiece, vibrato, vibrato bridge, vibrato tailpiece, vibrato bridge tailpiece, etc.

The forerunner of one such species, known as the fulcrum tremolo, Fender U.S. Pat. No. 2,741,146, shows and provides a tremolo device which incorporates a novel bridge structure which incorporates the tailpiece which is commonly known to provide the anchoring means for the strings. The bridge plate is also known as the base plate. The base plate upon which the individual bridge elements are adjustably secured has a beveled ridge portion mounted to the instrument body by six screws permitting pivotal movement about a fulcrum axis for varying the tension on the strings and producing the desired tremolo effect. Further, the bridge and the tailpiece both move together as the tremolo device is pivoted. A

singular aspect of the fulcrum tremolo is that the harmonic tuning is upset as the device is pivoted.

Typically, when a fulcrum tremolo pivots about its fulcrum axis, counter springs are utilized to counteract the pull of the strings. Counter springs are usually connected to the body of the instrument at one end and to an attachment means on the bottom of the tremolo at the other end. One of the most troublesome problems with prior art has been maintaining the initial tuning at proper playing pitch. When a musician plays on the string there is usually some kind of string stretch over time and, consequently, a lessening of tension that results in the overall tuning going out of balance. Similarly, the use of the tremolo itself may also introduce string stretch. Further, various factors such as the changes in the humidity of the atmosphere causing the wood in the neck and/or body of the instrument to swell often create subtle distortions in the instrument's geometry which would then in turn disturb the equilibrium point between the tension of the strings and the tension of the counter springs and then as a consequence disturb the initial position. Initial position refers to a specific equilibrium point between the tension of the strings and the tension of the counter springs at the intended tuned pitched condition of the strings. Often the pivot means is subject to wear and the tremolo does not always return to its initial position.

Improvements to the Fender U.S. Pat. No. 2,741,146 fulcrum tremolo have included using string clamps at the nut and immediately behind the intonation points on each of the bridge elements to limit string stretch to within these two points that define the scale length and separately adopting a novel beveled edge adjustably supported by two screw-like members positioned in the body at the fulcrum point to improve the return to initial position after pivoting the tremolo device (Rose U.S. Pat. No. 4,171,661). In Rose U.S. Pat. No. 4,497,236 a combination of the bridge element, the tailpiece and fine tuners replaced the "novel bridge

structure" incorporating the tailpiece of the Fender device so that within the limited range (typically less than a whole tone) the strings could be re-tuned without unlocking the string clamps at the nut. However, string stretch beyond the range of the fine tuners necessitated a correction that is tedious, and time consuming involving unlocking the string clamps, re-tuning the strings, re-adjusting the clamp, and re-tuning all the other strings to re-balance the equilibrium point back to initial position.

Therefore, for stringed musical instruments, as is known to those skilled in the art:

- the second critical point is a clearly defined point on the bridge or individual bridge elements, the adjustment of which relative to the first critical point on the nut defines the length of the string or scale length and is called harmonic tuning;

for fulcrum tremolos as originated by Fender U.S. Pat. No. 2,741,146 , when pivoted:

- both the bridge portions and the string anchoring means, the tailpiece, simultaneously move about a fulcrum axis;
- there is a tendency for the harmonic tuning to be upset; and
- various factors can disturb the equilibrium point between the tension of the strings and the tension of the counter springs and as a consequence disturb the initial position; and

for those fulcrum tremolos equipped with fine tuners as with Rose U.S. Pat. No. 4,497,236, Storey U.S. Pat No. 4,472,750 and Fender U.S. Pat No. 4,724,737:

- the fine tuners simultaneously move with the bridge and tailpiece portions about the fulcrum axis when the device is pivoted; and

- fine tuners are designed to offer the tuning of the strings a minor adjustment of pitch after the general tuning is first achieved by the tuning pegs on the head of the instrument; and

for those fulcrum tremolos fitted with string locks at the first and second critical points as in Rose U.S. Pat. No. 4,171,661,

- string stretch beyond the clamps at the first and second critical points is eliminated offering the most stability of tuning possible in regards to this set of problems associated with string stretch.

In Steinberger U.S. Pat No. Re. 31, 722 stringed musical instruments without tuning pegs placed in the typical fashion on the head of the instrument were commonly known as "headless" stringed musical instruments. The replacement tuning machines were mounted on the body opposite the side where the neck joins the body.

Takabayashi U.S. Pat No. 4,608,905 describes an improvement on fulcrum tremolos incorporating, "octave tuners", tuners which function like the tuning pegs at the head of the instrument but which is integrated into the tailpiece function in the tremolo means. The bridge portion of the device comprised a "roller" configuration for the second critical point similar to Storey U.S. Pat No. 4,742,750 and Steinberger U.S. Pat No.4,704,936. A cylindrical portion adjustably secured to the base plate houses a string holder member for one end of the string which is "fitted in such a manner as to be allowed to move freely in the axial direction". The ball end of each string is arranged to be anchored "to the rear end opening of the string holding members" which is adjustably positionable "in the stretching direction of the strings for effecting octave tuning". The string continues through the string holder member which is sufficient in size to ensure that the wrapping of

the ball end does not extend over the second critical point; the string then passes over the bridge element towards the nut. In this device the string holder member accomplishes the tailpiece function by anchoring the string at a single point which moves accordingly when the string holder member is displaced to achieve the tuning of the instrument.

Further improvements in the fulcrum tremolo utilized an arrangement with ball bearings at the pivot point within a housing adjustably mounted to the body which not only improved return to initial position after use of the tremolo but also virtually eliminated the wear and tear associated with prior art (McCabe U.S. Patent Application No. 07/607,458, Continuation No. 08/027,729, filed 1/14/93).

Additionally, the replacement of fine tuners with macro-tuners on a fulcrum tremolo (McCabe U.S. Patent Application No. 07/607,458, Continuation No. 08/027,729, filed 1/14/93) provided an intonation module that included a novel integrated one piece bridge-tailpiece structure secured to the base plate where each string anchored within its respective structure passes through a separate lever member and over the bridge element wherein the lever member could be displaced by an adjustment bolt to provide the means to bring and adjust the strings to playing pitch from an untensioned condition circumventing the re-tuning limits imposed by the fine tuner arrangements. These macro-tuners are often part of an intonation module dedicated to each string for use with but not exclusive to "headless" stringed musical instruments, that is, instruments without tuning pegs placed in the typical fashion on the head of the instrument. Certainly, a fulcrum tremolo with macro-tuners could be used with instruments which had tuning pegs without a disadvantage. Further, macro-tuners could be placed on the head or the

body of the instrument and if integrated with a string anchoring means could replace the tuning pegs.

Macro-tuners refer to tuners with the capacity to raise and adjust the tension of the strings from an untensioned condition to a proper playing pitch, and as such provide for alternate tunings and compensation for substantial string stretch during the life of the string essentially without additional means.

Often the musician is called upon to play in an ensemble where the other instruments are not tuned to a typical concert pitch. Accordingly, the musician must flatten or sharpen the initial tuning of all the strings on his instrument in order to meet the pitch requirements of other instruments. This re-tuning often disturbs the initial position because the tension of the counter springs has not been readjusted as well. Accordingly, the position of the base plate of the tremolo is either tilting away from or towards the body of the instrument which then can limit the range in which the tremolo can be activated. Steinberger U.S. Pat. No. 4,632,005 and Gunn U.S. Pat. No. 4,955,275 provide for an adjustable counter spring and utilize an adjustment knob that provides a means to vary tension of the counter spring and thereby maintain the equilibrium point between the tension of the counter spring and the tension of the strings on fulcrum tailpiece tremolo, that is, a tremolo device where the bridge elements do not pivot with the anchoring means and, therefore, do not upset the harmonic tuning as such. There is no prior art for this type of arrangement on a fulcrum tremolo.

An alternate means to tuning pegs on the head of the instrument has been proposed in a quick tuner arrangement design (McCabe U.S. Patent Application No. 07/607,458) wherein the tuning device, now known to those skilled in the art as a

"semi-headless tuner", has the capacity to individually anchor and bring the strings to playing pitch and then accomplishing the fine tuning. The primary tuning means is afforded by a forceps-like clamp at one end of a L-shaped arm with a plurality of "teeth" engaged with "teeth" on a holding bracket. This arrangement provides for a variety of locking positions that correspond to a variety of pre-set tuned conditions for the associated strings secured to the opposite end of the L-shaped arm. The secondary tuning means or fine tuning is provided by a small thumb screw adjacent the point where the string is secured to the L-shaped arm, however, this arrangement is subject to premature string breakage and a limited range.

Additionally, these improvements listed above are characterized by a number of other defects or limitations which will now be briefly indicated. The ball bearing means (McCabe U.S. Patent Application No. 07/607,458, Continuation No. 08/027,729, filed 1/14/93) for adjustably mounting the fulcrum tremolo to the instrument body are arranged in a bearing housing supported within a fork-like structure in the base plate. This placement of the bearing arrangement is often then too close to the pickups and prevents installation on some instruments. Further, for instruments being built to receive this design, the typical placement of the pick-up in relation to the second critical point is disturbed and may affect the tonal character of the instrument in an undesirable manner. Further, the fork-like portion that holds each bearing housing is delicate and is subject to breakage.

The design of the macro-tuners (McCabe U.S. Patent Application No. 07/607,458, Continuation No. 08/027,729, filed 1/14/93) requires the string to be bent severely to achieve the necessary tuning. This arrangement makes tuning at the higher pitches difficult and in some cases may introduce string breakage.

The "octave tuners" of the Takabayashi fulcrum tremolo U.S. Pat No. 4,608,905 anchor the strings at a point on the string holder member spaced on the

opposite side from the second critical point on the bridge elements. This arrangement presents serious problems:

- the length of the string subject to stretch beyond scale length, which includes the additional string length as measured from the bridge element to the anchoring point, is excessive in general practice at initial position and is far more so when the device is pivoted as would be seen in view of the improvements made by Rose U.S. Pat. No. 4,171,661 and,
- the tensioning of the strings which holds the ball end of the string securely against the outer opening of the string holding member is inadequate to keep the ball ends as seated throughout the performance range of the tremolo; such mis-seatings are devasting to the effort to maintain a tuned fulcrum tremolo.

SUMMARY OF THE INVENTION

Accordingly, the primary object of this invention is to provide improvements in the mounting means of the bearing and bearing housing arrangement for pivotally supporting the base plate of the fulcrum tremolo that will allow a greater range of installation possibilities.

It is a further object of the invention to provide the intonation modules with macro-tuners integrated with a string anchoring means, known to those skilled in the art as a tailpiece. The intonation modules each include a separate string tensioning element that functions to secure the string adjustably to the fulcrum tremolo. This string tensioning element is in threaded engagement with an adjustment bolt for positioning relative to the second critical point for accomplishing the macro-tuning. The string tensioning element includes a fork-like

string clamping means in bearing contact with a restricted portion within the a sleeve-like portion of the intonation module structure that remains stable through the full range of the tremolo and secures the string as close as possible to the second critical point in order to limit the length of string that would otherwise be subject to stretch. By threading the adjustment bolt, the string tensioning element is displaced simultaneously:

- increasing the tension of the associated string to a proper pitched condition and varying the tension of the string thereof so as to provide the macro-tuning function, and
- drawing the fork-like string clamping means of the string tensioning element within the restricted portion of a sleeve-like portion of the intonation module structure, compressing and closing the forks upon the string at the clamping point for transferring the anchoring of the string to an improved anchoring means positioned at the end of the string tensioning element closest to the second critical point.

Yet, another object of the invention is to provide a global tuning mechanism on the fulcrum tremolo which would compensate for the problems associated with varying humidity on the instrument as well as other factors that could affect the instrument's geometry. Further, a global tuner would also provide a simple and quick means for the musician to adjust the initial position in order to meet the pitch requirements in varied situations. Further, the global tuner in re-establishing the initial position allows the full range of pivoting the tremolo in either direction. Global tuners refer to a means on a fulcrum tremolo with the capacity to adjust the equilibrium point between tension of the counter spring(s) and the tension of the strings in order to compensate for changes in tension on the strings or the counter springs. The global tuner employs a thumb screw-like means with an additional

reverse-threaded shaft on the opposite side of the thumb wheel; one side one of the two shafts is threadedly engaged with the spring attachment means on the tremolo and the other of the two shafts is similarly engaged with a separate counter spring holder. The counter springs are attached to the body as in prior art on one end and to the separate spring holder on the other. When the thumb screw is threaded the relative distance between the spring attachment means on the base plate of the tremolo and the attachment point of the springs to the body can be adjusted, thereby varying the tension of the counter springs in order to compensate for the variations in tension of the strings associated with redefining or re-establishing the initial position.

Another object of the invention is to replace the fine tuner portion on each of the L-shaped arms of the "semi-headless tuners" with an additional macro-tuner mechanism and, therefore, provide for greater range and easier use. This advancement for adjustably securing each string to a improved clamping means positioned within a sleeve-like portion on one end of a L-shaped arm provides the capacity to tune the string from an tensioned condition to pitched string condition. As in prior art each L-shaped arm can pivot and be selectively positioned to a number of pre-set positions relative to the nut or first critical point for raising from an untensioned to a pre-set pitched string condition. A variant of this arrangement eliminates the L-shaped arm and positions a plurality of macro-tuners integrated with a string anchoring means at the nut wherein the clamping means is positioned at the first critical point to eliminate string length that would be otherwise subject to stretch as compared to those found in conventional tuning peg arrangements.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages

and specific objects attained by its use, reference should be had by the accompanying drawings and descriptive matter in which there are illustrations and described preferred embodiments of the invention.

BACKGROUND OF THE INVENTION

In the drawings:

FIG. 1 is a plan view of an electric guitar embodying the present invention.

FIG. 2 is a perspective view of the macro-tuners, bearing mounting arrangement and global tuner of the present invention as used in the electric guitar.

FIG. 3 is a side view cross-section of the tremolo mechanism showing the macro tuners, bearing mounting arrangement and the global tuner.

FIG. 4 is a top view cross-section of the ball bearings, the housing mounting means.

FIG. 5 is an exploded perspective view of the bearing ball bearings, the housing mounting means.

FIG. 6 is a side view of the "semi-headless tuners" with two macro-tuning means.

FIG. 7 is a top view of the "semi-headless tuners" arranged on the neck of the guitar adjacent the nut.

FIG. 8 is a cross-section view of the side of a macro-tuning mechanism.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1, an electric guitar 1 is illustrated comprising a head 2 at one end, a body 3 at the other end, with a neck 4 extending between the head and the body. Six strings 6 extend from head 2 to body 3 over neck 4. Neck 4 forms fret board 5 for guitar 1. At head 2, each of the strings extends over nut 7 forming the first critical point for the strings. Nut 7 is located at the transition of neck 4 to head 2. Each string 6 is secured on the head by anchor 8 and each anchor has a corresponding tuner 9. On the body 3, strings 6 are secured to fulcrum tremolo 12. Fulcrum tremolo 12 has arm 11 for pivoting the tremolo and providing the vibrato effect on the strings. Fulcrum tremolo 12 has six intonation modules 13. The intonation modules present improvements to the macro-tuning invention which incorporates the function of the bridge element and tail-piece in its structure as well as the capacity to adjustably secure the individual strings to the instrument. The intonation modules are movable and thereby provide a means to change the distance between the first and second critical points or the harmonic tuning as such.

The invention is shown for us on electric guitar 1 and it should be understood that the invention could be used on a variety of stringed musical instruments.

In body 3 of guitar 1 there are electric pickups.

In the following description, fulcrum tremolo 12 will be described in greater detail.

Fulcrum tremolo 12 forms a second critical point for strings 6, sometimes characterized as an intonation point or bridge point.

In FIG. 2, fulcrum tremolo 12 is shown on an enlarged scale compared to FIG 1. FIG 3 displays fulcrum tremolo 12 of FIG 2 in a cross-section view. The second

critical point is located near the front intonation modules 13. Outwardly from intonation modules 13 on each side of the opposite sides of base plate 14 extending in the direction of the strings there are bearing housings 30 . The bearing housing 30 supports base plate 14 pivotally relative to body 3. Global tuner 50 is positioned between spring block 40 extending downwardly from the bottom of base plate 14 and counter springs 44 connected to instrument body 3.

In FIGS. 2 and 3, one of the intonation modules 13 is shown including a shaped barrel-like base 10 with a second critical point formed at string opening 17. Base 10 is adjustably secured to base plate 14 of fulcrum tremolo 12 by machine screws 28 through slots 29. Loosing machine screws 28 permits longitudinal movement of base 10 and associated parts for harmonic tuning of string 6. Adjustment bolt 18 first passes through opening 20 in base 10 and threaded portion 19 of adjustment bolt 18 is engaged with threaded portion 21 of string tensioning element 22 within sleeve-like portion 23 of base 10. String 6 of the musical instrument makes critical contact with base 10 at the string opening 17 to passageway 15 sloping downwardly and rearwardly through base 10 until the string passes into a sleeve-like portion 23. String 6 continues passing through clamping point 16 of string tensioning element 22, through slots 25 between upper fork 72 and lower fork 73 of fork-like string clamping means 24, through string passageway 27 of string tensioning element 22 and is secured at exit 26. Annular flange-like portion 71 of fork-like string clamping means 24 of string tensioning element 22 is in bearing contact with restricted portion 70 of sleeve-like portion 23 of base 10. Threading adjustment bolt 18 displaces the string tensioning element 22 relative to string opening 17 providing an adjustment whereby tension or pull on string 6 is applied and varied for raising and adjusting the strings 6 from an untensioned condition to a pitched string condition; simultaneously, annular flange-like portion 71 of fork-like string clamping means 24 of string tensioning

element 22 is drawn within restricted portion 70 of sleeve-like portion 23, clamping string 6 between upper fork 72 and lower fork 73 at clamping point 16 adjacent to string opening 17.

In FIGS 2, 3, 4 and 5 outwardly from intonation modules 13 on each side of the opposite sides of base plate 14 shown at the forward end of fulcrum tremolo 12 extending in the direction of the strings, there is bearing housing 30. Bearing housing 30 is adjacent to base plate 14. Housing 30 is adjustably supported relative to body 3 of the instrument by threaded post 31 with annular flange 32. Post 31 is threaded into insert 33 in body 3. By threading post 31 into insert 33, the spacing between body 3 and housing 30 is selectively adjustable. Adjustment of post 31 is effected through an oval opening 34 in the top of housing 30. In housing 30 rearward post 31, there is opening 76 extending transversely of the string direction of guitar1 containing bearing assembly 35, formed by four side-by-side roller bearings 36. Insert 37 fits into cut-out 38 in the side of base plate 14 with pin 39 with annular flange 39a extending outwardly through bearings 36. Annular flange 39a on pin 39 spaces the side-by-side roller bearings 36 from base plate 14. Accordingly, by manipulating tremolo arm 11, fulcrum tremolo 12 can be pivoted about pin 39 to achieve the desired tremolo effect.

As can be seen in FIGS. 2 and 3 there is spring attachment means 40 extending downwardly from base plate 14. The preferred embodiment incorporates thumb screw 42 with shaft 45 threadedly engaged with threaded opening 47 in spring block 40 on one side of thumb screw 42 and another shaft 46 with reverse threads in the opposite direction of shaft 45 threadedly engaged with reverse threaded opening 48 in spring holder 41. Counter springs 44 are attached at one end to spring holder 41 and to body 3 on the other end of counter springs 44. Guide pin 43 extending outwardly from spring block 40 towards spring holder 41 passes through guide pin opening 49 in spring holder 41 limiting longitudinal

rotational movement of spring holder 41 relative to spring block 40. By threading thumb screw 42 clockwise relative to spring holder means 41, spring holder 41 moves closer to spring block 40 increasing the tension of the counter springs 44 and by threading thumb screw 42 counter-clockwise relative to spring holder means 41, spring holder 41 moves away from spring block 40 decreasing the tension of the counter springs 44 providing the means to adjust the equilibrium point and globally tune fulcrum tremolo 12.

FIG. 6 displays an improved "semi-headless" tuner arrangement for stringed musical instruments.

In FIG. 7, at the end of 4 is shown with strings 6 each of a different size. The strings 6 pass over nut 7 and each string is secured by string tensioning tuning device 51, a "semi-headless tuner" adjacent the nut. There is a separate macro-tuning device 52 for each string.

The devices, as set forth in FIGS 6 & 7 includes bracket 53 secured to and projecting from the end of neck 4. L-shaped lever 54 is pivotally connected by pin 55 as shown in FIG 6. The other or second arm 56 of lever 54 extends from pivot pin 44 toward the end of neck 4.

At the end of second arm 56 there is sleeve-like portion 57. String slot 58 extends longitudinally along sleeve-like portion 57 continuing disposed at an angle towards the top of the sleeve. Slot 59 at the free end of the sleeve extends towards the connected end of second arm 56.

Adjacent the free end and within sleeve-like portion 57, there is string clamping means 60 with fork-like portion 61 with upper fork 62 and lower fork 63 and at the opposite end there is threaded opening 64. Thumb screw 65 passes through slot 59 in sleeve-like portion 57 and through unthreaded opening 66 in upper fork 62 and is threadedly engaged with threaded opening 67 in lower fork 63. String 6 is arranged through slotted opening 58 and into slotted opening 75

between upper fork 62 and lower fork 63. Threading thumb screw 65 clamps the upper fork 62 and lower fork 63 on string 6, securing string 6 to string clamping means 60.

Adjustment bolt 68 is adjustably mounted within sleeve-like portion 57 opposite the free end. Threaded portion 69 of adjustment bolt 68 is threadedly engaged with threaded opening 64 adjustably securing string clamping means 60 to macro-tuner 52. By threading adjustment bolt 68 the clamping means can be displaced relative to nut 7 wherein the tension on string 6 can be raised and varied whereby the macro tuning can be achieved.

In FIG. 8, shows a single macro-tuning device where string 6 passes through slots 58 of sleeve-like portion 57 and is arranged between upper fork 62 and lower fork 63 of fork-like portion 61 of string clamping means 60 and clamped and secured by thumb screw 65 wherein threaded portion 69 of adjustment bolt 68 is threadedly engaged with threaded opening 64 of string clamping means 60. By threading adjustment bolt 68 the position of string clamping means 60 relative to the anchoring means at the opposite end string 6 is increased and varied whereby tension or pull on string 6 is applied and varied for raising and adjusting the strings 6 from an untensioned condition to a pitched string condition.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.